1. Introduction

Mutation testing is a way of testing where bugs (mutations) are seeded into your program and then the tests are run. If the tests fail then the mutations are killed. If not then the mutations are alive. The quality of your tests can be gauged from the percentage of mutations killed.

The purpose of this lab is to explain why mutation testing is important and should be used as an addition to other software testing methods, and introduce one of the mutation testing tools PIT.

Analysis Tool

The tool used in this lab is PIT mutation testing system which has a plugin for Eclipse. It applies a configurable set of mutation operators (or mutators) to the byte code generated by compiling your code.

System Under Test

You will be amending a test suite for MinBinaryHeap.java class, a minimum binary heap implementation.

2. Tasks

**Task 1: Playing Code Defenders online (~30 minutes)**

To get the general idea of how the Pitest plugin works you will first play a game online. Go to [http://code-defenders.org/](http://code-defenders.org/) and create a user (takes less than a minute). The TA will create a battleground where half of the students play as defenders and the other half as attackers.

To join the game, go to games -> Open games, scroll down to battlegrounds. The TA will tell you the game ID and you can join as a defender or an attacker. One of the deskmates should choose the defender role and the other one the attacker role. If you prefer to do your homework alone choose the defender role.

**Attacker:** You will start the game by seeding a bug in the original code. A bug can be one small change at a time (e.g. changing a variable name, changing one operator). For example, the conditional boundary operator is changed:

```java
public void goDown() {
    if (currentFloor > 0)
        currentFloor--; 
}
```

**Defender:** Your task is to write unit tests to kill the mutants generated by the attackers. When there are no mutants alive, write a test that will kill a possible future mutant. Write at least 1, but not more than 2 assertions, no loops, no new methods, no calls to System.*.

An example of a test:

```java
import org.junit.*;
import static org.junit.Assert.*;

public class TestElevator {
    @Test(timeout = 4000)
    public void test() throws Throwable {
        Elevator e = new Elevator(10, 2);
e.addRiders(1);
        assertEquals(1, e.getNumRiders());
    }
}
```

To see the changes made by other students simply refresh the page.
**Equivalent mutants**

It is possible to create a mutant which is identical in functionality to the code, so no test can pass and fail on the mutated class.

For example, the following functions are identical in behavior, they are equivalent:

```java
public void addRiders(int numEntering) {
    if (numRiders + numEntering <= capacity) {
        numRiders = numRiders + numEntering;
    } else {
        numRiders = capacity;
    }
}
```

```java
public void addRiders(int numEntering) {
    if (numRiders + numEntering > capacity) {
        numRiders = capacity;
    } else {
        numRiders = numRiders + numEntering;
    }
}
```

If a defender believes that an attacker's mutant is equivalent, they can click the "Claim Equivalent" button on the mutant. After this, the attacker will see that their mutant was marked as equivalent. If the mutant is equivalent, they should accept it as equivalent.

However, if the mutant isn't equivalent, the attacker can prove that it isn't by writing a test which kills it.

**Rules and more information about the game:** [http://code-defenders.org/help](http://code-defenders.org/help)
Task 2: Tool Setup

For Eclipse:
Set up Eclipse IDE, install PITEST plugin from here: [http://marketplace.eclipse.org/content/pitclipse](http://marketplace.eclipse.org/content/pitclipse) and import the project “MinBinaryHeap” from the course wiki page.

Use the default settings as shown below:
Window -> Preferences -> Pitest

![Preferences](image1.png)

Default Mutators

![Preferences](image2.png)
**For IntelliJ:**

Go to the plugins section on the welcome page of IntelliJ IDEA (2020) or go to Preferences -> Plugins. In the search box, type the name of the plugin “PIT mutation testing” and install it.

![Plugin installation screenshot](image)

Then, import the project “MinBinaryHeap” that you downloaded from the course wiki page.

Add a new Run Configuration

Run -> Edit Configurations -> Add new configuration (green plus button)
Configure the source and test folder accordingly. Click Apply and Ok.

**PS!** If you for some reason get an exception when running tests (java.lang.NoClassDefFoundError: org/hamcrest/SelfDescribing) then add Hamcrest library to the classpath as shown here (underlined lines):
For more information: http://stackoverflow.com/questions/14539072/java-lang-noclassdeffounderror-org-hamcrest-selfdescribing/22975179#22975179
**Task 3: Amending the test suite**
You are given a test suite with 71% mutation coverage and 94% line coverage. Your task is to write more tests to kill most of the remaining mutants and look for bugs (here we mean the bugs that were in the code before the mutation testing started).

PIT tool can be launched:
Run As -> PIT Mutation Test (Eclipse) or Run PIT (or whatever you named in the set up for IntelliJ).

Result should be displayed in the bottom side of IDE.
For Eclipse in the PIT Mutations tab, coverage report is in PIT Summary tab -> MinBinayHeap.java
For IntelliJ, click Open report in browser for mutation coverage report.

*Light green* shows line coverage; *dark green* shows mutation coverage. *Light pink* shows lack of line coverage; *dark pink* shows lack of mutation coverage.

The goal is to kill mutants and fix the bugs. Once you find a bug, fix it and continue to look for more bugs.

For this lab you should submit a ZIP folder containing the following:

1. **PDF report including:**
   - A list of found bugs (with brief statement what is wrong)
   - A list of the added test cases.
   - PIT mutation coverage and line coverage statistics
   - Bonus: A list of equivalent mutants with explanations (if found)

2. **Fixed code** and amended test suite

Anything that is not mentioned in the file will not be reckoned during the grading process.
3. **Grading**

You can get up to 9 points for this lab, plus up to 1 bonus point.

**The grading is as follows:**

1) **Up to 1 point for the list of bugs (with brief explanation what is wrong)**
   You will get maximum points for finding two or more bugs with your added test cases. For each listed bug, clearly state what is wrong, in which code lines the corrections have to be made, and which test case found the bug.

2) **Up to 1 point for the list of added test cases**
   You will get maximum points for listing all test cases that you added to the test suite. Follow Lab 2 instructions on how to list test cases.

3) **Up to 5 points for improving the test suite**
   You will get points for reporting the mutant and line coverage statistics. You may get up to 5 points for the achieved mutation coverage as follows:
   
   - >90% killed mutants – 5p
   - >85-90% killed mutants – 4p
   - >80-85% killed mutants – 3p
   - >75-80% killed mutants – 2p
   - 70-75% killed mutants – 1p

4) **Up to 2 points for the fixed code and amended test suite**
   You will get maximum points for including the code of the corrected program and the code of the (amended) test suite.
   IMPORTANT: If the program or test code is missing, or the lab supervisors cannot execute your code, all points you received under point 4 will be cancelled.

5) **Up to 1 bonus point**
   There may be some cases where PIT has generated equivalent mutants. If you find any, point them out and shortly describe why they are equivalent. You get 0.5 points for each correctly identified equivalent mutant but not more than 1 bonus point in total (even if you find more than 2 equivalent mutants).
   Mutants are called **equivalent** when they are behaviorally equivalent to the original program (i.e., the program to which the mutation operation was applied).